Chapter 7
Project Performance Monitoring

7-1. Purpose of Performance Monitoring

Beach nourishment has become a preferred method for controlling erosion and mitigating storm damage. Construction of a beach fill project represents a long-term commitment to a staged construction plan where the beach fill is reconstructed periodically to maintain the desired design over the life of the project. Design dimensions will vary during the life of a given construction fill. Usually the design dimensions are determined to provide optimum protection from storms over a wide frequency range based on theoretical or laboratory models of design profile response. These models are necessarily conservative in order to account for the lateral and vertical variations that are characteristic of actual beach erosion and the ill-defined storm condition. The degree of natural rebuilding following a storm, or the occurrence of two or more closely spaced storms, is generally not addressed in the selection of the minimum cross section. Additional fill is placed to absorb the losses expected between reconstruction events and is theoretically adjusted to reflect the effects of borrow material on the long-term average loss rate. These losses reflect natural recovery of the native beach and an average of mild and extreme storm years. In the event of a single severe storm or an unusually stormy season, it may be necessary to schedule reconstruction earlier than anticipated. Under extreme circumstances, it may even be necessary to place emergency fills in order to avoid consequential damages. Beach fills operate as sacrificial structures in a dynamic environment, which makes it imperative that their condition and performance be monitored (see EM 1110-2-1004, Coastal Project Monitoring). The primary objectives for monitoring a beach fill project are as follows:

a. To document and assess project performance to determine how well it fulfills the protection requirements for which it was designed.

b. To identify maintenance and renourishment requirements.

c. To evaluate project impacts.

d. To assess the behavior of the borrow area.

Accomplishing these objectives should follow a three-phase approach, which includes field data collection of required information, data analysis, and project assessment.

7-2. Fill Placement Monitoring

A monitoring plan for the fill placement area consists of four major components: beach profile surveys, beach sediment sampling, wave and water level measurements, and aerial shoreline photography. These four components define the minimum requirements for documenting and assessing the performance of a beach nourishment project. The monitoring process should begin before the placement of any material. Long-term and seasonal cycles of beach profile change and sediment distribution should be evaluated to determine the characteristics of the active native beach which is also an important part of the design phase. Short-term and long-term assessment of project behavior is required to understand and document the redistribution of the nourished profile into a more naturally shaped profile as a result of the dominant coastal processes. The re-sorting processes of the fill occur as a result of wave and current action which hydraulically separate the new fill material into a more natural grain size zonation and cause rapid adjustments of the fill immediately after placement. Consequently, it is recommended that post-fill monitoring begin as soon as material is placed on a given segment of the project area.

a. Baseline data. It is very important that historical data on the native beach as it existed before the project be collected, compiled, and available for comparison with post-project monitoring results. However, sufficient data may already exist for the native beach during the pre-project study. Pre-project and historical data required for the monitoring of such a project are described in Chapter 2 of this manual. In many instances, some of the data are discarded after project completion, particularly sediment samples. Without this valuable data, further studies and investigations of the project area are seriously hampered or precluded. It is therefore important to retain all data and sediment samples of the native beach. This is not only for comparison with monitoring data but as an irreplaceable scientific resource.

b. Beach profile data. Periodic surveying of profile lines in and adjacent to the project area before and immediately after placement of fill is the primary method of evaluating changes in dune, beach, and nearshore morphology. Selection of profile locations depends on the type of project, such as beach fill adjacent to an inlet or jetty, beach fill on a continuous shoreline, etc. The number of profile locations within the nourished area depends on the length of fill area and its proximity to inlets or other shore-normal structures. Spacing between profiles is site-specific;

however, care should be taken so that the profiles are of sufficient density to cover all areas of the fill placement. Monitoring of the Storm Protection Project at Ocean City, MD (USACE 1989), has used profile lines spaced at approximately 300 m (1,000 ft) for primary surveys, and 600 m (2,000 ft) for secondary surveys which are intermediate in time between primary surveys. To reduce costs, a minimum number of profiles which adequately characterize all aspects of the project should be monitored.

(1) Control profile locations a minimum of 1.6 km (1 mile) updrift and downdrift of the project area should be monitored to compare the behavior of the nourished beach with the natural beach profiles at the time of monitoring. The control profiles are also necessary to measure the longshore movement of the fill material out of the project area. The number and locations of control profiles are site-specific and depend on project length, volume of fill material placed, longshore transport rates, and seasonal drift reversals. The control profile locations should not be under the influence of any other projects, since the purpose of the control is to compare the behavior of fill to the natural beach. If a project is near an inlet, profiles updrift and downdrift of the inlet should be monitored to determine the influence of inlet processes on fill movement.

(2) All profiles must be correlated to known benchmarks, which are fully documented and easily re-occupied in the future. The profiles should originate from a stable point on the beach (behind dune crest, seawall, or bluff line) and extend on a repeatable line normal to the shoreline as far out into the water as possible. The offshore portion of the profile should be collected using a profiling sled or standard fathometer and should extend to the profile depth of closure to characterize the active limits of fill response. The recommended time frequency of profile collection is presented in Table 7-1, but should be done at least annually.

(3) Many beaches are naturally fortified by sand dunes located in the back-beach area. The effectiveness of dune protection depends primarily on dune height, stability, and continuity. Some beach fill operations on dune-backed beaches involve modification of the dunes, either by placement of fill directly on the dune field or by construction, creating a wider berm which increases the supply area for onshore winds to transport material to the dunes. Dunes in the project area, particularly the foredunes directly inland of the beach, should periodically be surveyed to determine changes occurring in the topography as a result of nourishment. Surveys of the profile lines established in

Table 7-1
Optimum Beach Profile and Sediment Sampling Scheme

Year	Times/Year	Number of Profiles	Sediment Samples
pre-	2	Collect within fill and control profiles summer and winter months to characterize seasonal profile envelope	Core and surface samples at time of profile collection (beach and offshore) to characterize native sediments and seasonal distribution
post-	1	Collect all profiles immediately after fill placement at each profile location for documentation of fill placement volume	Surface samples taken immediately after fill placement to characterize fill material during profile
1	4	Four quarterly trips collecting all profiles to depth of closure	Surface samples during profiles
2	4	Same as year 1	Same as year 1
3*	2	6-month sampling of all profiles to depth of closure	Surface samples during profiles
4	1	Annual collection of all profiles to depth of closure	Surface samples during profiles
storm	-	Collection of all profiles to depth of closure as soon as weather permits after a major storm event (20-year storm or greater)	Surface samples during profile

* If project is a single nourishment event.

NOTE: If project is to be renourished within the above 4-year time period, the sampling schedule should repeat beginning from the post-fill immediately after renourishment to document volumes and temporal behavior of newly placed fill.

the monitoring study will indicate large-scale changes. Integrity of the dune defenses depends largely on crest height continuity. Potential critical areas of low foredune elevation may occur between the established profile lines. It is therefore desirable to survey a shore-parallel dune crest height profile of the foredunes at more closely spaced data points than the profile line spacing.

(4) Profile surveys should be conducted using sled survey apparatus. These systems are accurate and simplistic in design and are considered to be the best methods for collecting high-accuracy beach survey data. For areas not accessible by sled, surveys can be collected by conventional land survey methods on the dry beach out to wading depth and boat-mounted acoustic fathometers for submerged portions of the beach system.

c. Beach sediment sampling. Sediment samples should be collected for each profile line during the time of survey. A minimum of three samples should be collected on each profile at the following locations: mean high water (mhw); mid-tide level (mtl); and mean low water (mlw). In areas that are not under tidal influence, such as the Great Lakes, corresponding sediment samples should be collected at the following locations: base of dune, bluff, or seawall; mid-berm; and waterline. Sampling at the base of the dune or seawall is suggested if that location is subject to frequent storm and wave action.

(1) Stauble (1988) found that in order to comprehensively monitor the sediment redistribution across the entire profile, surface samples can alternatively be collected at selected morphological features such as the mid-berm, berm crest, step, bar trough, bar crest, and the seaward bar slope at the depth of closure as discussed in Chapter 2. This sampling characterizes the hydrodynamic zonation of the sediment distribution as the fill material readjusts, rather than sampling at fixed distances from a shore reference point regardless of profile shape.

(2) Core samples should also be collected at selected locations for selected profiles during the pre-nourishment data collection. These samples are used to characterize the variability in native beach seasonal and storm-related sediment distribution (Anders, Underwood, and Kimball 1987). Although the core sampling locations are project-specific, it is suggested that the mid-berm, berm crest, mid-tide, and step be adequately sampled.

(3) The recommended temporal and spacial schedule for project sediment sampling is presented in Table 7-1. The time scheduling for sediment sampling is basically the same as the profile scheduling.

d. Storm events. Extreme events, such as a major storm, often exert a pronounced and long-lasting effect on coastal areas. It is for this reason that the immediate effects of the event on the project area and the amount of recovery after the return of normal conditions are important items of information. To evaluate the effects of an extreme event, a data collection effort should be made as soon after the event as conditions permit. Plans should be provided in advance for this purpose so that minimum time elapses between the event and the commencement of field data collection. The items to be monitored and methods used for post-storm data collection are basically the same as used for scheduled surveys with an essential minimum of:

(1) Storm wind, wave, and surge data.

(2) Beach profile survey data.

(3) Sediment characteristics data.

e. Beach fill monitoring data analysis. Analysis of the profile monitoring data should include: profile volume change and shape readjustment; areas on profile of erosion and accretion; volume of fill remaining within the project area; assessment of fill movement in both alongshore and cross-shore directions; and seasonal storm response. Analysis of sediment data should include: grain size statistics of native and fill material; documentation of grain size readjustment over the monitoring time period; seasonal and storm grain size response; and assessment of fill and renourishment factors for future fill design requirements.

(1) Stauble and Hoel (1986) documented short- and long-term project behavior and design guidelines. They examined project behavior 1 year after placement and important coastal processes influencing fill distribution. This indicated that the volume of fill remaining within the project is a function of several related physical factors as well as wave components. The amount of fill placed per unit length of beach may be a predictor of project response within the first year of placement.

(2) Past projects have shown that borrow suitability is an important parameter on project longevity. The selection of sediment sampling locations to be used for suitability analysis was examined by Stauble, Hanson, and Blake (1984) and found that a composite of mhw, mtl, and mlw samples gave the best representation of both the native beach and post-fill sediment characteristics. Furthermore, offshore grain size distributions changed little over the monitoring period. Suitability analysis, which includes offshore samples, was found to bias the native beach towards better suitability with finer borrow material, thus

resulting in a misrepresentation of overfill and renourishment calculations.

(3) Long-term data analysis will allow examination of project seasonal patterns in both the profile and sediment response. This analysis should also bracket major storm events in order to assess the protection provided by the nourishment project. Information of this nature is rarely available to document fill project behavior.

7-3. Borrow Area Monitoring

Monitoring procedures for the borrow area will depend on the type of borrow area being used. Borrow area types include offshore, inlet shoals, sand traps, bay or lagoons, and terrestrial sources. The principal purpose for monitoring borrow sites is to evaluate borrow fill suitability, continuing changes in morphology and sediment characteristics, and biology of the area after completion of the borrow operation. Borrow monitoring data collection should include bathymetric and sub-bottom surveying, sediment core and surface sampling, and biological data collection before excavation, and bathymetric and biological data collection after excavation. This section primarily addresses borrow sites in water-covered areas. Terrestrial borrow sites generally exhibit little or no change in topography and sediment characteristics after completion of the borrow operation.

a. Bathymetric and bottom profiling. Once a borrow site is selected, removal of material from the borrow site will affect its morphology. The nature of the modification depends on whether the material was obtained by excavation of a thin superficial layer over a large area or deep pits in a comparatively small area. One objective of borrow site monitoring is to determine to what extent existing processes will tend to restore the original morphology or create new forms. For this reason, bathymetric surveys are needed to monitor the site after the borrow operation.

b. Borrow area sampling scheme. Borrow area sampling time and collection requirements are presented in Table 7-2. Borrow area monitoring does not require data collection as often as the project site; however, a minimum of 1 year between sampling is recommended.

c. Changes in processes. Changes in bathymetry due to offshore borrow operations can modify the characteristics of incoming waves. These changes are primarily related to refraction and bottom friction. Dredging fill material from ebb tidal shoals is a likely source of wave modification because these shoals lie close to the shore and their crests are at relatively shallow depths.

Table 7-2
Borrow Area Bathymetry and Sediment Sampling Scheme

Year	Times/year	Number of Samples
pre-	1	Cores to characterize borrow material and access fill suitability. Bathymetry and sub-bottom sampling covering expected borrow sites and control areas.
post-	1	Surface sediment grab samples to characterize post dredging borrow area sediment distribution. Bathymetry of post-dredged surface to assess fill volume removed.
last	1	Cores to characterize infilling sediment grain size distribution. Bottom surface baththymetry to determine infilling volume.

(1) During pre-project planning and design, these factors will have been evaluated on the basis of theoretical considerations and indicate wave modification judged to be acceptable. However, it is possible that unforeseen effects may occur. These will usually be indicated by accelerated erosion or accretion of the project beach and/or adjacent shore areas. During post-project monitoring, any unusual erosion or accretion of the project area or adjacent beaches should be investigated with the possibility that it is resulting from modification of offshore borrow sources.

(2) Another type of process modification due to borrow operations can occur where inlets and associated shoals are dredged for borrow material. The strength and set of tidal currents in the inlet and shoal areas can be altered by the removal of material. In such cases provisions should be made for current observations as well as bathymetric and sediment data.

d. Borrow area data analysis. Analyses should include evaluation of temporal borrow changes, determination of the rate and volume of borrow area infilling, and identification of current patterns in the borrow area channel or basin.

7-4. Shoreline Change

Historical shoreline trends and project-related shoreline orientation along the entire length of the project and control areas should be analyzed. This type of analysis can reduce the number of ground surveys necessary to characterize project behavior. Aerial photography and ground photography can serve as valuable documentation of project conditions during pre- and post-fill monitoring.

a. Aerial photography. Aerial photography overflights of the project area should be performed at regular intervals. Use of aerial photographs provides a cost-effective method to assess the behavior of the entire project and adjacent shoreline areas. The photographs can be utilized to construct a base map with shoreline change throughout the project period. Coverage should include a single flight line with 60-percent overlap stereo coverage of the entire project shoreline including the control profile locations. Black and white, color, or color infrared film should be used. The scale of the photographs should be sufficient to identify shoreline features. A scale of 1 in. to 500 ft is suggested for the base map and aerial photography. Proposed aerial flight times during the project monitoring are presented in Table 7-3 and all efforts should be made to coordinate overflights with ground surveys.

Table 7-3
Recommended Aerial Photography Collection Scheme

Year	Times/Year
pre-	1
post-	1
1	3
2	3
3	3
4	2

Note: Overflights should follow the post-fill schedule after each nourishment

b. Aerial photo data analysis. Data analysis should include shoreline changes and profile changes from pre- and immediate post-construction. The analysis should be repeated biannually thereafter to cover post-maintenance dredging. The products provided will consist of tables and maps on shoreline change rates and volume calculations of fill remaining at each flight time. The reporting of such data will augment the ground database of historic shorelines to determine the readjustment rates of accretion and erosion along the project and control area shoreline. Figure 7-1 illustrates an example of using aerial photographic techniques to assess shoreline changes due to the placement of beach fill for a beach nourishment project at Indialantic/Melbourne Beach, Florida. Such techniques are important to document the entire project behavior and response with a minimum investment of cost and time.

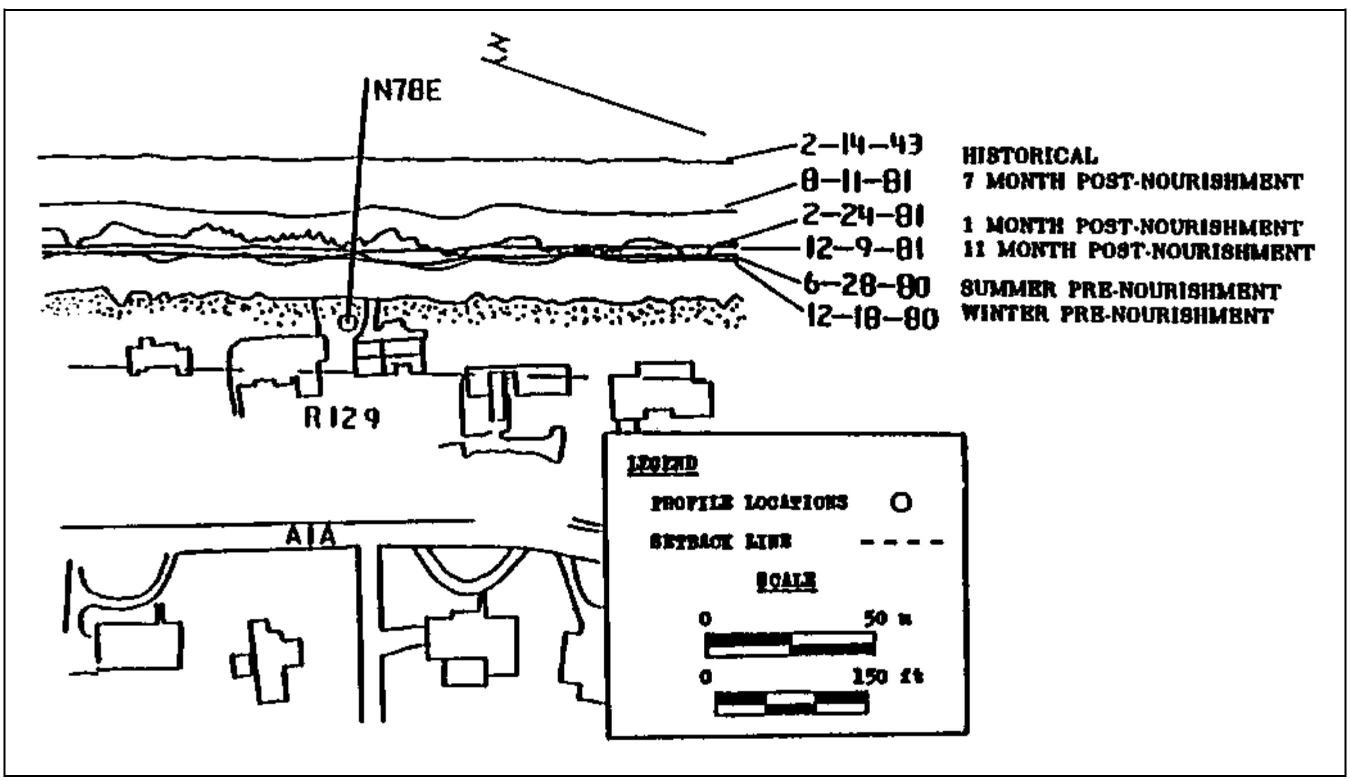


Figure 7-1. Aerial photographic assessment of shoreline change due to beach fill placement at Indialantic/ Melbourne Beach, FL (after Stauble and Hoel (1986))

7-5. Littoral Environmental Monitoring

Environmental physical elements such as wave, longshore current, and meteorological data should be collected to understand the coastal processes that occur in the project area. Measurements of this type are needed on a continual basis in order to compare short- and long-term variations of physical factors with temporal changes in the dune, beach, and nearshore morphology and sediments. Collection of wave data is an integral part of any evaluation of a coastal engineering erosion mitigation project. Wave-driven coastal processes are a controlling factor in the response of the native and nourished beach. Major profile and sediment changes can be expected during fill placement and during the monitoring period, as the fill material readjusts to the local wave climate. The project may change the physical parameters or respond adversely to the prevailing coastal processes or extreme events. Establishing a cause-and-effect relationship between the waves and project response is essential in predicting future fill behavior.

a. Wave data collection. The most accurate way of obtaining wave data is the use of a wave gauge that gathers frequent measurements of wave height, period, and direction of propagation and transmits the data to a recording device. Numerous types of wave gauges are available and are most commonly deployed in buoys, on the seafloor, or attached to the seaward end of piers and jetties. These data will provide information on longshore currents and provide the ability to assess movement of the fill in the downdrift direction. It may be required that some types of gauges be removed during the winter months when the likelihood of severe storms and ice is the greatest. It is important to plan to reinstall the gauge when conditions permit. A better practice is to install gauges suitable for continuous monitoring, since the major storms of greatest interest are likely to occur after seasonal gauges have been removed.

(1) A less costly alternative to wave gauges is to utilize observers to estimate wave characteristics using techniques developed by CERC for their ongoing Littoral Environment Observation (LEO) program (Schneider 1981). The LEO program also covers other physical factors such as wind and longshore currents. A LEO data form is presented in Figure 7-2. LEO observations should be collected after project completion, ideally performed on a daily basis, and continue through the completion of the monitoring program. Because LEO observations provide information on wave direction and other important physical parameters such as wind velocity, longshore currents, breaker type, and foreshore slope, it is recommended that a LEO program be implemented even when wave gauges are being used. Information about LEO programs, forms, equipment, and training can be obtained from the Coastal Geology Branch, CERC, U.S. Army Engineer Waterways Experiment Station, P.O. Box 631, Vicksburg, Mississippi, 39181-0631.

b. Littoral environmental data analysis. Analysis of physical coastal processes data and fill response data will lead to understanding of forcing functions and the response of beach fill to these processes. The behavior of fill is a result of complex interactions between the physical forces. Changes of cross-shore profile and sediment will occur as the fill readjusts to the dynamic equilibrium forces caused by the physical processes. Alongshore readjustment will occur in areas of strong longshore transport as the fill acts as a feeder beach to the adjacent downdrift area.

(1) Documentation of fill behavior during storm activity should be used to assess the protection provided by the project against design storms. Determination of quantities of fill remaining after storm occurrences versus the intensity of the storm will facilitate decisions on renourishment intervals and volumes.

7-6. Biological Monitoring

Excavation and placement of fill material usually impact the biology of the area directly involved. Biological impacts may also be created in adjacent areas from the turbidity created by the excavation process. For this reason biological surveys of both the beach and borrow area should be performed. Monitoring of the borrow site should include assessment of the infauna, sea grasses, reefs, or other biologically sensitive areas adjacent to the borrow area. The beach project area may also have environmentally sensitive areas such as sea turtle nesting sites, bird nesting areas, beach organisms, nearshore reefs, and sea grasses.

a. Biological sampling. Biological sampling should consist of grab samples of the borrow area and quadrate samples of the beach areas to identify the infauna of the borrow and fill locations. Monitoring turbidity in the borrow site and in the surf zone of the fill area may be necessary to assess the impact of dredging and dumping of fill material on the local biota. A more detailed outline of biological sampling can be found in EM 1110-2-1204.

b. Biological data analysis. Data analysis should evaluate fluctuations in the flora and fauna in the beach fill and adjacent nearshore area, effects of turbidity on fauna at the beach fill and borrow site, and the effects of the borrow operation on the borrow site organisms. The time and extent of recovery of native organisms should be verified and compared to that of control areas. The absence of native organisms or the appearance of new organisms should also be verified and documented.

LITTORAL ENVIRONMENT OBSERVATION
RECORD ALL DATA CAREFULLY AND LEGALLY

SITE NUMBERS
1 2 3 4 5

YEAR
6 7

MONTH
8 9

DAY
10 11

TIME
12 13 14 15

WAVE PERIOD

Record the time in seconds for eleven (11) wave crests to pass a stationary point. If calm record 0.

16 17 18

BREAKER HEIGHT

Record the best estimate of the average wave height to the nearest length of a foot.

19 20 21

WAVE ANGLE AT BREAKER

Record to the nearest degree the direction the waves are coming from using the protractor on the following page. 0 if calm.

22 23 24

WAVE TYPE

0–Calm
1–Spilling
2–Plunging
3–Surging
4–Spill/Plunge

25

WIND SPEED

Record wind speed to the nearest mph. If calm record 0.

26 27

WIND DIRECTION

Direction the wind is coming.
1–N 3–E 5–S 7–W 0–Calm
2–NE 4–SE 6–SW 8–NW

28

FORESHORE SLOPE

Record foreshore slope to the nearest degree.

29 30

WIDTH OF SURF ZONE

Estimate in feet the distance from shore to breakers, if calm record 0.

31 32 33 34

LONGSHORE CURRENT

DYE

Estimate distance in feet from shoreline to point of dye injection.

36 37 38

CURRENT SPEED

Measure in feet the distance the dye patch is observed to move during minute period; if no longshore movement record 0.

43 44 45

CURRENT DIRECTION

0 No longshore movement
+1 Dye moves toward right
−1 Dye moves toward left

46 47

Figure 7-2. Littoral Environmental Data (LEO) sheet (continued)

RIP CURRENTS

If rip currents are present, indicate spacing (feet). If spacing is irregular estimate average spacing. If no rips record 0.

49	50	51	52

BEACH CUSPS

If cusps are present, indicate spacing (feet). If spacing is irregular estimate average spacing. If no cusps record 0.

54	55	56

BEACH WIDTH

Measure the distance of the most seaward Beach Berm crest from a reference point to the nearest foot.

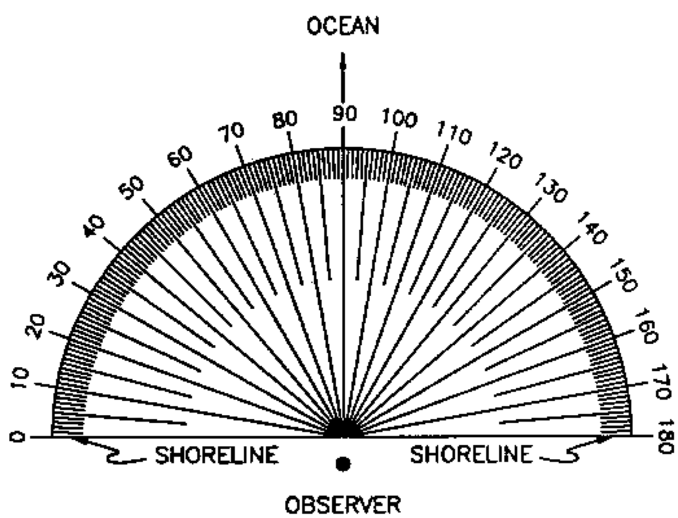
57	58	59	60

PLEASE PRINT:

SITE NAME ______________________ OBSERVER ______________________

Please Check The Form For Completeness

REMARKS: ____



NOTE: If a pier is used for an observation platform: place 0–180 line on the rail parallel to the centerline of the pier, sight along the crest of the breaking waves and record the angle observed.

Figure 7-2. (Concluded)